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Micromorphology and genesis of terra rossa of the U.S.S.R. and East Europe

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Terra rossa [1] is a red loamy product of weathering generally lying on top of karst limestone. It is particularly typical of the arid area of the Mediterranean and also widely developed in East Europe, in the area of Hercynian massifs and south of them, in some areas of the Carpathian and Balkan mountains and in the Crimea.

Terra rossa has been studied for more than a hundred years mainly by means of field observations and chemical analyses. Its mineralogical composition and micromorphology has not been properly investigated, while the results of micromorphological and mineralogical studies lead to essential revision of ideas about the composition and origin of these formations.

The main problems which are discussed in this paper are as follows:

(1) structural and genetic relations of terra rossa with underlying limestone;

(2) principal features of the composition of terra rossa and their genetic significance;

(3) identification of original rocks from which the red material was formed.

1. Elucidation of relations between terra rossa and underlying limestone is a point of particular significance.

According to the most popular "theory of residuum", terra rossa is eluvium of the underlying limestone or residuum from its gradual solution. This assumption which was made in the middle of the last century [8] is still very popular.

Outcrops often reveal a distinct contact between red loams and underlying white limestone. In this case it is evident that terra rossa is not eluvium of the limestone. But in some cases the upper part of the limestone is saturated with red substance and a clear contact cannot be visually observed. This creates an impression of gradual transition of the limestone into the red mass.

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[1] In Czechoslovakian literature it is červenozem, in German — die Roterde.

The author has made a thorough investigation of the micromorphology of a transitional layer between pure limestone and red loam. In all cases it is clearly seen that the red mass is inwashed into the limestone from above filling up fine cracks and cavities. Gradual transition from the red loam to pure limestone resulted from inwashing of red particles by seepage water and not from residual accumulation of particles during solution of limestone. Less resistant components of limestone, generally basal cement, were solved, while fragments of shells were more resistant (Fig. 1).

Absence of genetic relations between limestone and overlying red formations in also proved by the results of spectral analyses. The data obtained (Table) do not show any relations between the content of trace elements in limestone and in the main component of terra rossa-fraction of particles smaller than 0.001 mm.

Table. Content of trace elements in the main components of terra rossa and underlying limestone, in 1.10^{-3} %

Trace element	Accuracy of determination	South Carpathians (Rumania)		Crimea (U.S.S.R.)	
		fraction <0.001 mm	underlying limestone	fraction <0.001 mm	underlying limestone
Ti	1	300	60	183	6
Mn	1	5.8	150	8	14
V	1	2.6	—	4	—
Cr	1	2.6	—	2	—
Ni	1	2.8	—	3	—
Co	1	1	—	1	—
Cu	0.1	14	0.5	4	1
Zn	3	9.2	—	11	4
Pb	0.1	2.2	—	1	0.7
Sn	0.1	0.1	—	0.1	—
Be	0.1	0.1	—	0.1	—
Ga	3	1	—	3	—
Zr	2	2	—	2	—
Sr	2	1.6	20	2	38

2. The composition of red formations is highly unhomogeneous. Large particles are represented by unrounded fragments of underlying limestone or well rounded fragments which were subject to long transportation. For example, the terra rossa of the mountain plateaus of the Crimea contains rounded fragments of milk-white quartz, in some areas of North Hungary it contains pebbles of bauxitic rocks and in other places — limestone pebbles.

The content of sand particles (0.1-1.0 mm) generally does not exceed 10% and that of silt particles (0.01-0.1 mm) is about 20%. In some cases

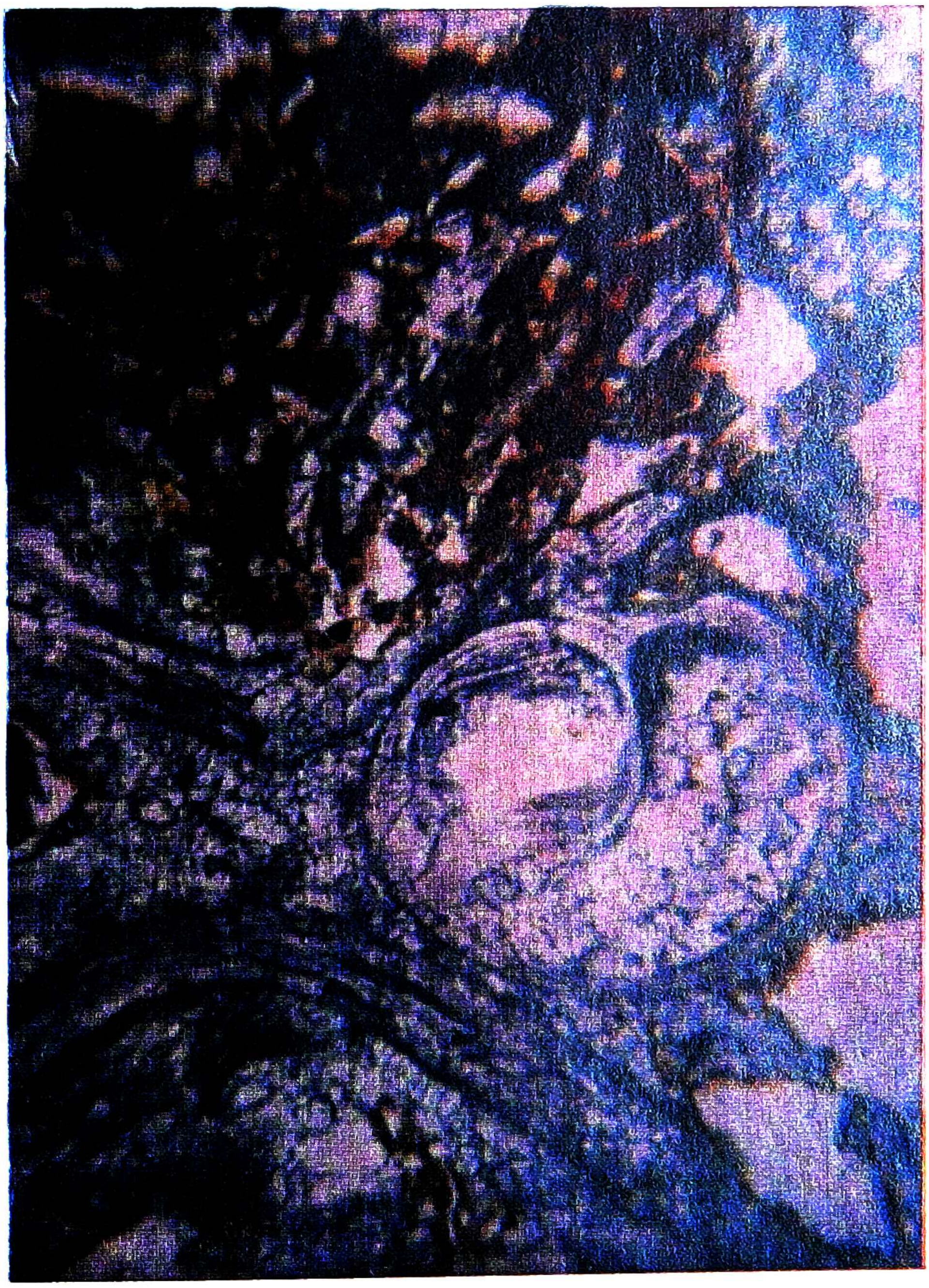

Fig. 1. Inwashing of the terra rossa substance into Sarmathian limestone. The red substance "impregnates" the limestone depositing on the sides of solution cavities. Magnif. ×90.

the amount of 0.01-1.0 mm fragments is quite small. Such was the case with the red formations of the South Carpathians. Sand and silt fractions are mainly represented by quartz. The content of clastic minerals with a specific gravity of more than 2.9 is generally 1 or 3% of the weight of granulometric fraction. Prevailing among heavy minerals are iron manganese concretions, ilmenite, barite (the latter refers to the Crimea). The fraction of particles smaller than 0.1 mm contains such resistant minerals as zircon, tourmalin, disthen, staurolite, garnet, spinel, rutile, as well as clinozoisite and epidote. Somewhat less frequent is hornblende.

About 50% of the weight of the red formations consist of particles

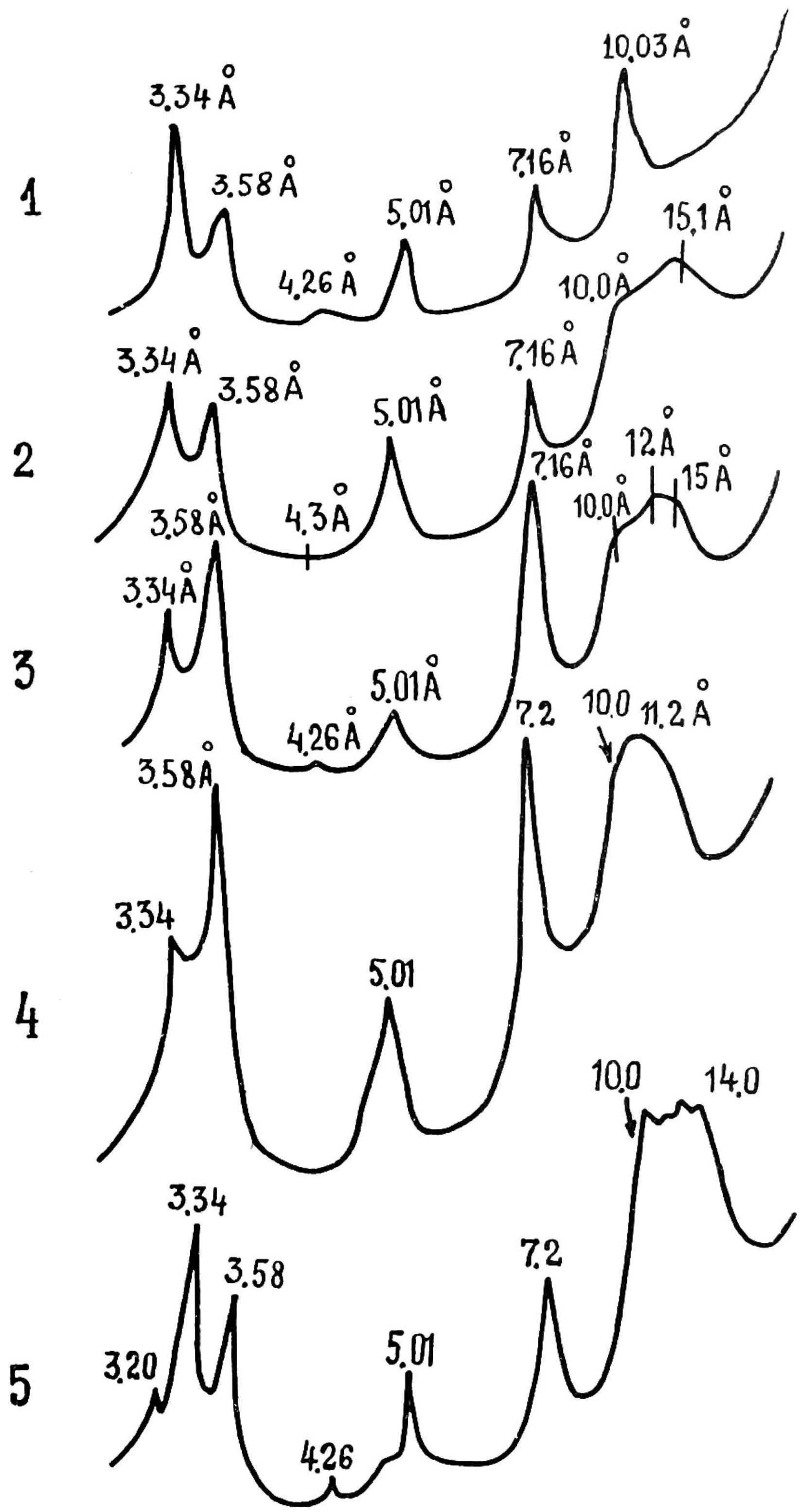

Fig. 2. Diffractogram of the fraction < 0.001 mm of terra rossa. *1, 2, 3* — the Crimea, *4* — the South Carpathians, *5* — Dobrudzha.

smaller than a micron. For the purpose of studying the mineralogical composition the fraction of particles smaller than 0.001 mm was subject to X-ray diffractometer analysis (analysed by B. P. Gradusov). The difractometer curves given in Fig. 2 show that prevailing are dioctahedral hydromica and partly shift-layer minerals. Also present are minerals of kaolinite group which are particularly frequent in the terra rossa of the South Carpathians and Central and South Slovakia.

Such conclusions have been proved by the results of electron microscope and thermography investigations (Fig. 3).

Still very popular is the assumption that red formations contain great amounts of free iron hydroxide. Antipov-Karatayev and Prasolov [1],

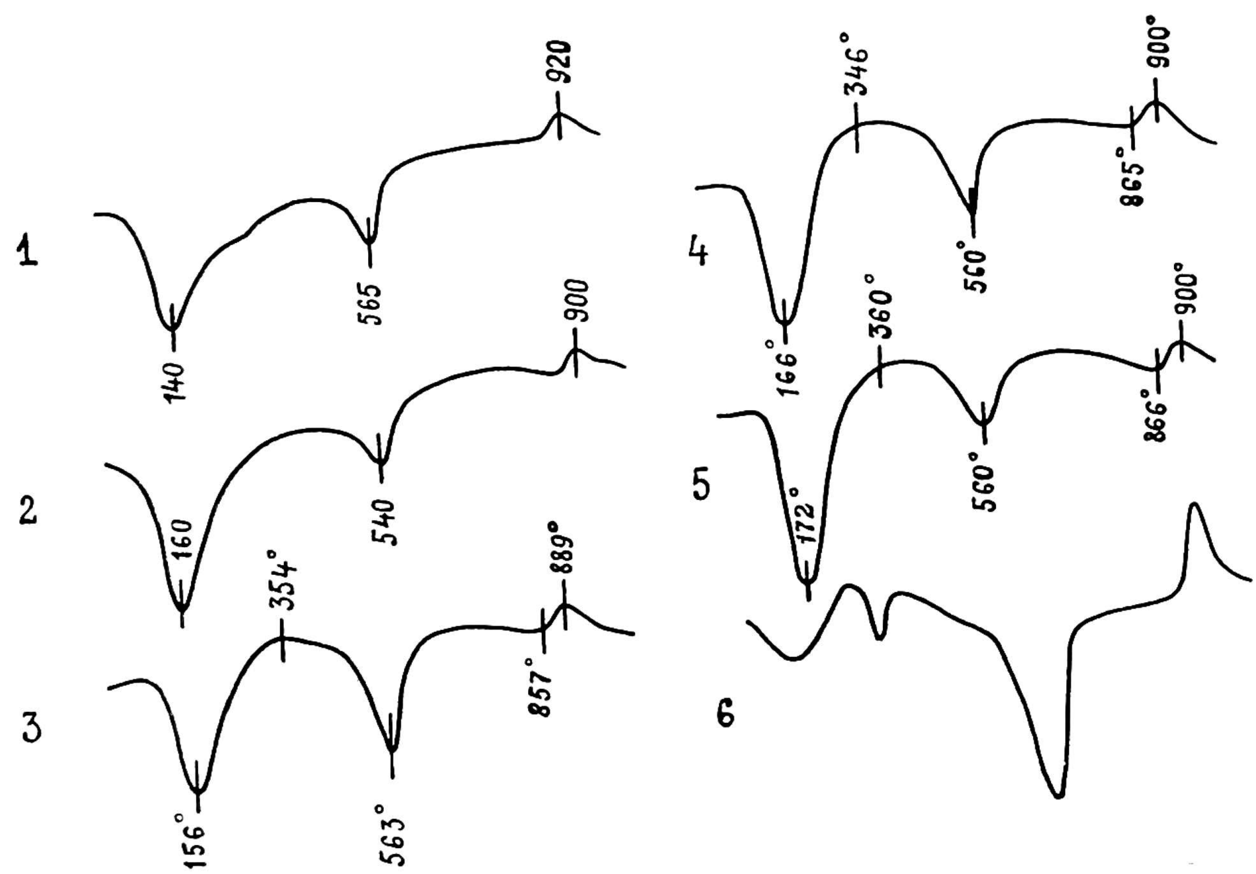

Fig. 3. Differential heating curves of the fraction < 0.001 mm of terra rossa. *1* — the South Carpathians, *2* — Dobrudzha, *3*, *4*, *5* — the Crimea, *6* — Slovakia (data of Andrusov).

Gladtsin and Dzens-Litovskaya [2], Blanck [6], Harrassowitz [7] and many other investigators believed that formation of terra rossa was mainly related with outwashing of iron from soil, transportation of this element and its accumulation on top of limestone. The red colour of terra rossa was explained by the presence of free iron oxide.

Determination of free iron oxide has been made by means of identification of this metal in extractions of 1-NHCl and 0.1-NH_2SO_4. It has been found that terra rossa contains a very small amount of mobile iron. The content of iron in the extractions of 0.1-NH_2SO_4 has been found to be less than 0.01% and it the extractions of 1-NHCl — generally not more than 0.5% of the specimen weight. The colour of the specimens has not changed after extraction.

The colour of red formations has been studied by means of a spectrophotometer. It has been found that the colour of terra rossa is due to absorption of light mainly in a short-wave part of the spectrum. The intensity of the colour is directly related to the content of diffuse silicate. The 0.10-0.25 mm and 0.25-0.5 mm fractions are of a very slight red colour though they contain free iron hydroxide in the form of microconcretions.

Ferric iron is not free in red formations but is fixed with diffuse silicate which leads to high refraction of these minerals. Red hydromicaceous minerals in all the specimens of terra rossa, collected over an extensive area from West Czechia to the Crimea have identical crystal optic constants: $N_m = 1.580\text{-}1.590$; $N_g - N_p = 0.018\text{-}0.023$.

Similar mineralogical composition of terra rossa from different areas results in a very close chemical composition. The SiO_2 content is never less than 40%. It is due to the fact that the SiO_2 content in clay minerals varies from 40% (kaolinite) to 50% (hydromica). Owing to the presence of clastic quartz, the SiO_2 content in terra rossa is generally 55-65%. The composition and amount of clay minerals control the content of Al_2O_3 (10-30%), Fe_2O_3 (6-15%) and fixed H_2O (5-8%). Always present is K_2O due to a great amount of hydromica minerals. Fig. 4 shows a very small scatter of the results of chemical analyses.

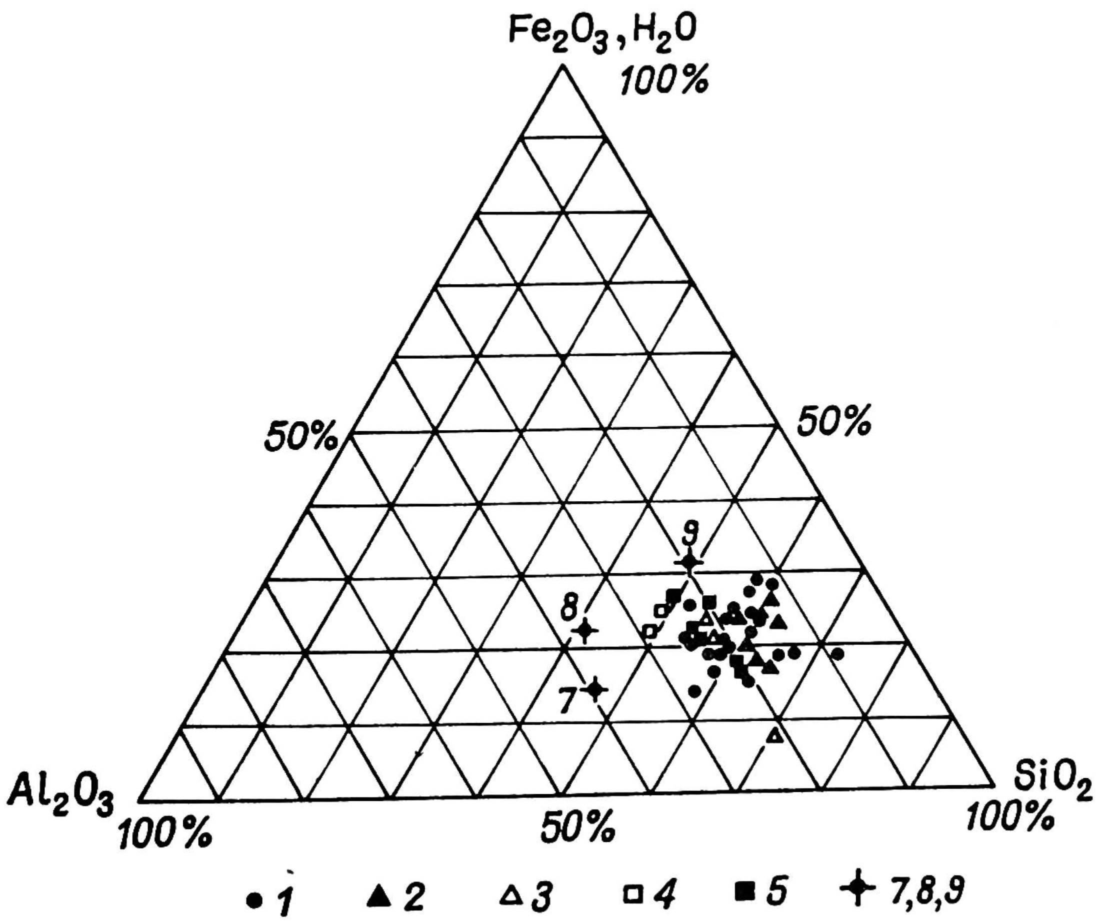

Fig. 4. Chemical composition of terra rossa from different areas. *1* — the Crimea, *2* — North Italy, *3* — Hungary, *4* — Slovakia, *7* — halloysite, *8* — kaolinite, *9* — ferric hydromica.

Thus, the main components of terra rossa from different areas are hypergene diffuse silicates and clastic quartz. This mineral association corresponds to the composition of a typical crust of weathering of silicate igneous and metamorphic rocks. Accessory minerals are represented by resistant ones (ilmenite, zircon, disthen, staurolite, etc.) which were generally preserved in ancient crust of weathering.

3. Great efforts have been needed to find out what was the original material of which terra rossa was formed.

The author assumed that there must be a place bearing the remnants of that crust a weathering from which terra rossa was formed as a result of washing and redeposition. Searches were crowned with success. Czechoslovakian geologists found remnants of ancient crust of weathering in Central Slovakia [5] and the author — in the Crimea and South Carpathians [4].

These crusts of weathering were mainly formed in Miocene though in some places their formation began in Paleogene. Under the conditions of warm humid forest landscapes intensive solution of limestone took place and huge karst was formed. At the same time silicate rocks were being weathered. The original rocks of crusts of weathering were andesite, their tuffs and partly crystalline schists in Slovakia, effusive rocks of different composition in Rumania and intrusive rocks of medium composition — in the Crimea.

When studying thin sections prepared from crusts of weathering, it has been found that weathering of hypogenic silicates (plagioclase, pyroxene, amphibole, mica) resulted in formation of diffuse hypergenic silicates (hydroclorite, hydromica, kaolinite). This formation occurred with wide development of hypergenic metasomatosis phenomena (Fig. 5).

In late Neogene forest landscapes were reduced in area due to aridization of climate. It resulted in intensive erosion of crust of weathering.

Great contribution into accumulation of red material was made by limestone. Surface water containing suspensions of weathering products was neutralized by interaction with limestone and suspended particles precipitated. Fine suspensions deposited in cracks and clay particles as well as larger debris — on the surface of limestone. Redeposited red mass fully preserved principal features of the mineralogical composition of the original crust of weathering.

SUMMARY

Terra rossa are red argillaceous formations (red beds), associated with limestones. Their age is generally neogene. These formations are typical of arid Mediterranean landscape and they are widely developed in East Europe, in the area of Hercynian massifs and south of them, in some areas of the Carpathians, the Balkan mountains and the Crimea.

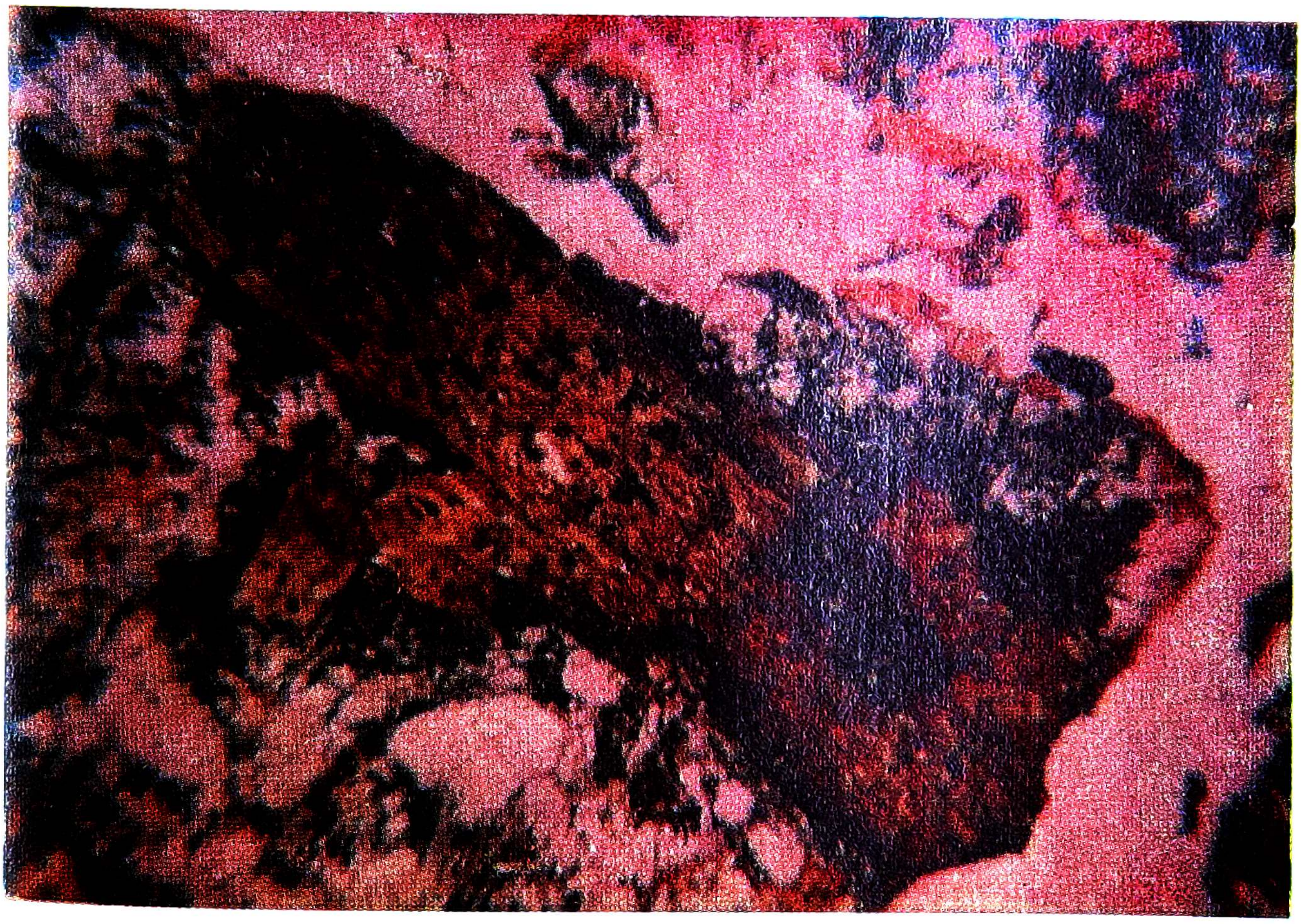

Fig. 5. Metasomatic replacement of hornblende crystal by ferric hydromica in the diorite-porphyrite crust of weathering of the Crimea. Magnif. ×90.

The author investigated the mode of occurrence, granulometric and mineralogical composition and micromorphology of terra rossa in the above mentioned area.

The composition of terra rossa is non-uniform. Large fragments are represented by limestone, silt particles — by quartz. Heavy fraction generally contains resistant minerals which vary from place to place. The main components of terra rossa are fine dispersion minerals. They are mainly represented by mixed-layer minerals (hydromica-montmorillonite) and also contain varying amounts of mineral of a kaolinite-halloysite group. The content of free hydrons serric and aluminium oxides (extraction 01 N, H_2SO_4 and 10% HCl) is negligible.

The fine-dispersion mass of terra rossa is highly coagulated as a result of its saturation by calcium ions. Very typical are strong aggregates which form complicated microtextures.

As a result of the conducted investigations, the author developed an original hypothesis of the terra rossa genesis.

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